

# Initial findings

## Prototyping a Landsat-8 Sentinel-2 Global Burned Area Product

David Roy, Jian Li, Hankui Zhang, Haiyan Huang, Adam Dosch, Sanath Kumar

Geospatial Sciences Center of Excellence, South Dakota State University,  
Brookings, SD 57007, USA

### Sentinel-2 Preliminary Experiences Session

Winter Landsat Science Team Meeting,  
Newman Library Multipurpose Room,  
Virginia Tech, Blacksburg, VA  
January 12-14 2016

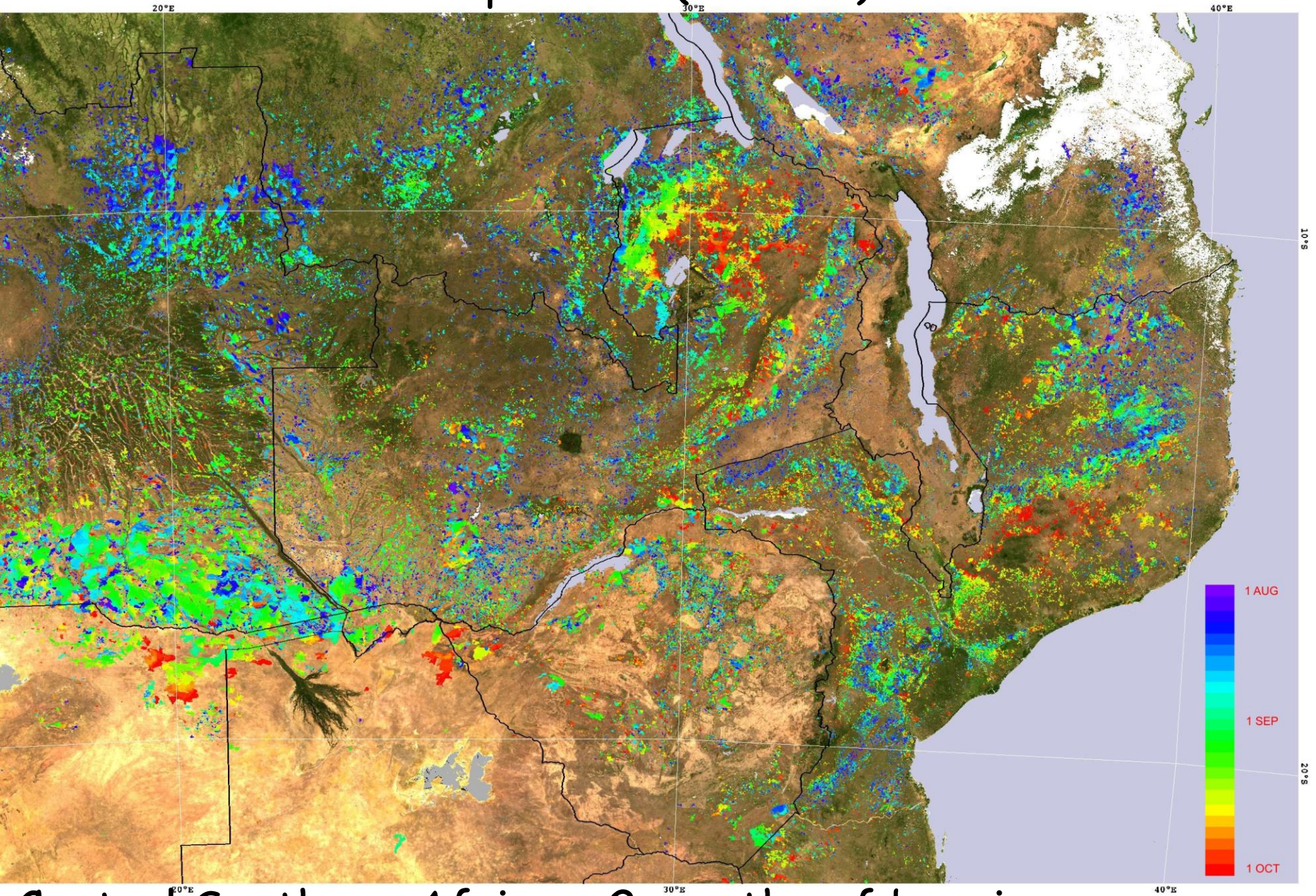


# Prototyping a Landsat-8 Sentinel-2 Global Burned Area Product funded by NASA NNH14ZDA001N Land Cover/Land Use Change (LCLUC14-2): Multi-Source Land Imaging Science

- Develop and validate an automated Landsat 8 & Sentinel 2 burned area 30m mapping product building on experience of
  - MODIS burned area product generation
  - WELD product generation
- Research & development plan
  - integrate Sentinel 2 with Landsat 8 under WELD processing
  - apply algorithm for all Africa & select global samples
  - validate with Planet Labs imagery & ground based measurements



# MODIS burned area product (MCD45)



Central Southern Africa - 2 months of burning





Movie:

**5 Months of 500m MODIS mapped  
burning, Okavango Delta, Botswana**

**Roy, Lewis, Justice, *RSE*, 2002**



# Global WELD 30m Landsat 5 & 7 surface reflectance normalized BRDF adjusted reflectance composite

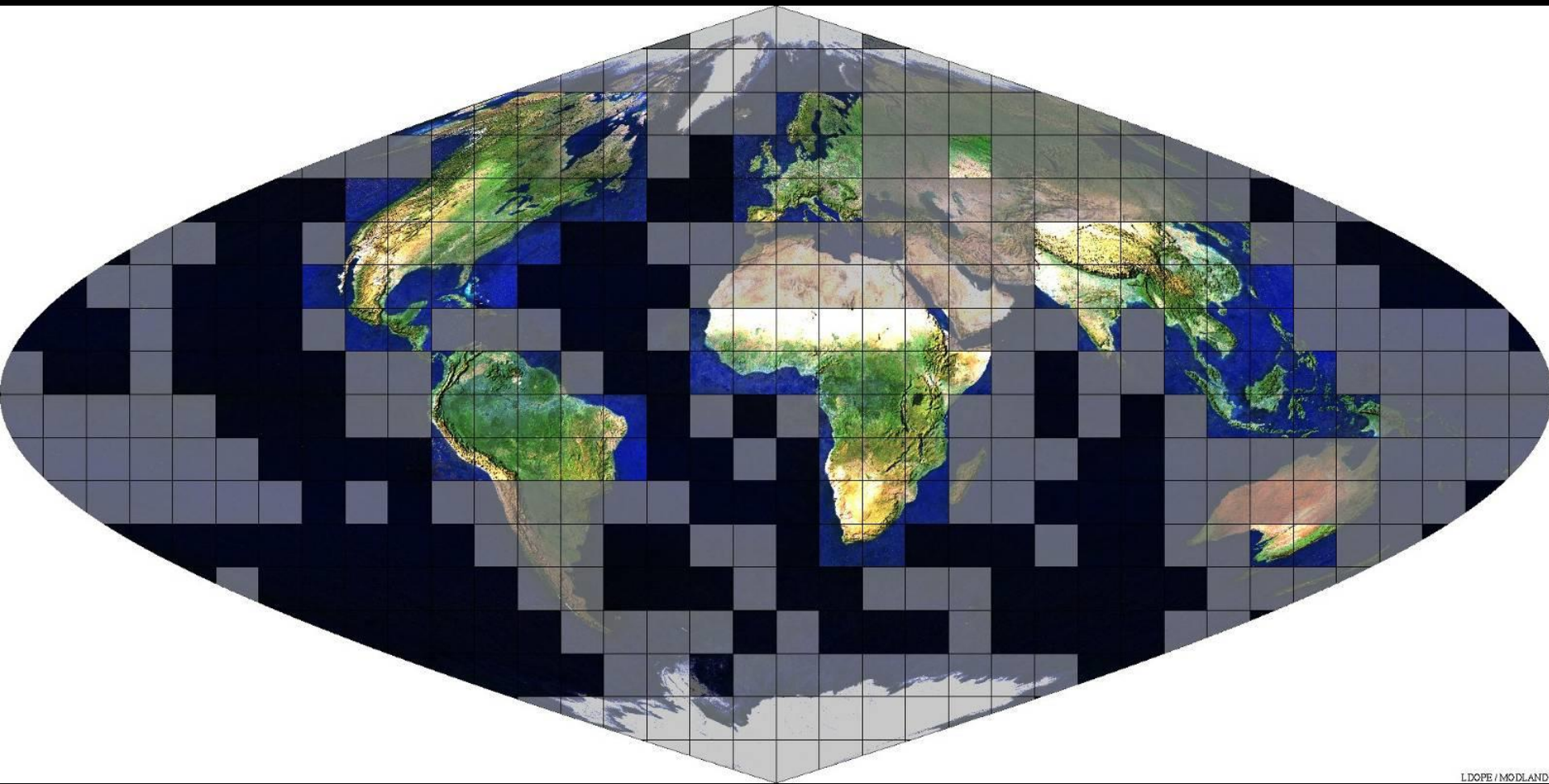


**Global WELD NEX Version 3.0** Annual 2009 30m product  
from 141,098 L1T scenes (59,183 Landsat 5 & 81,915 Landsat 7)

Sinusoidal Equal Area Projection



# Global WELD products nested to MODIS standard Level 3 products



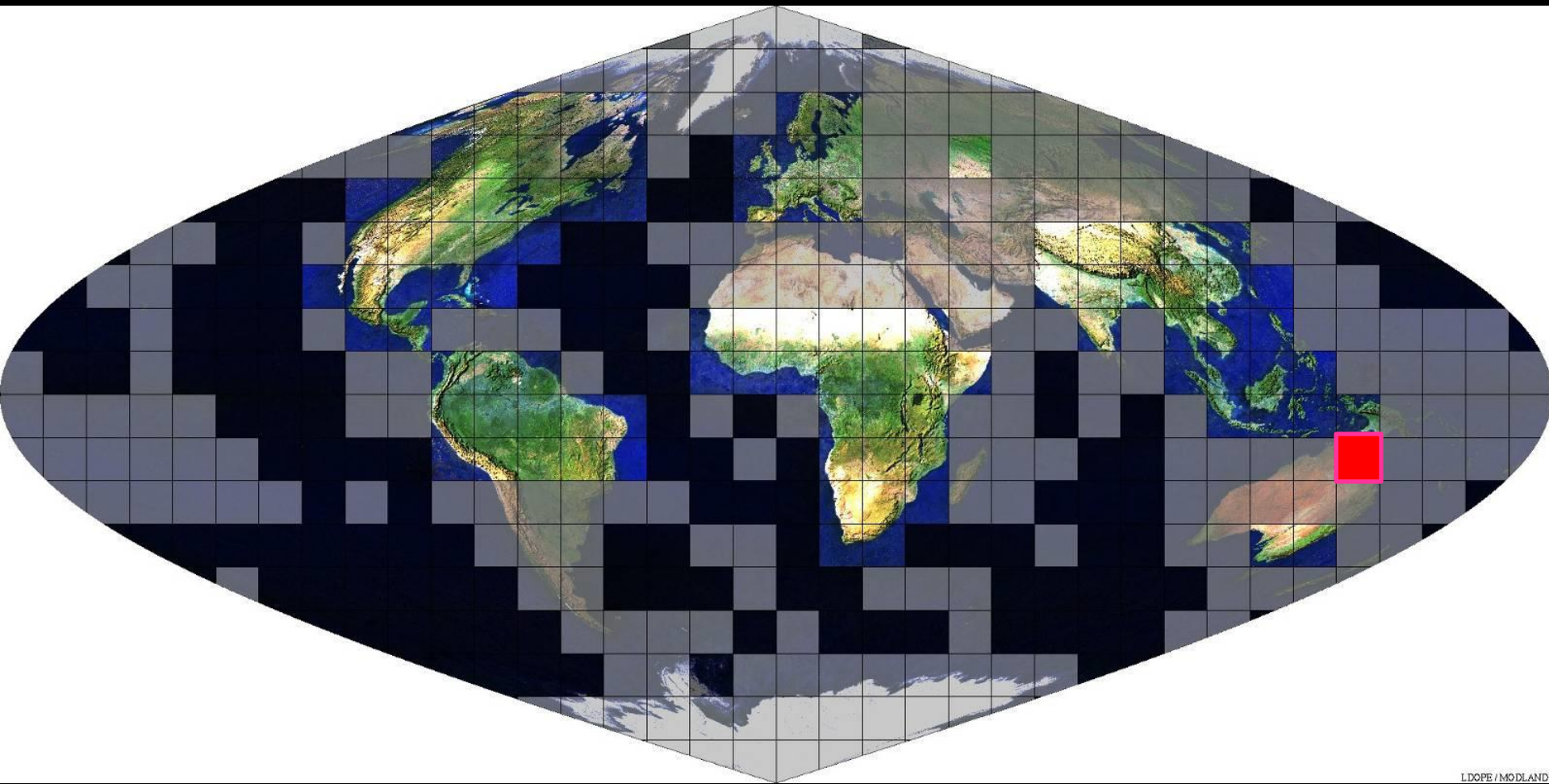
L. DOPE / MODLAND

Each MODIS tile has an area of approximately 1200 x 1200 km ( $10^{\circ} \times 10^{\circ}$  at the equator)

Sinusoidal Equal Area Projection



# Global WELD products nested to MODIS standard Level 3 products



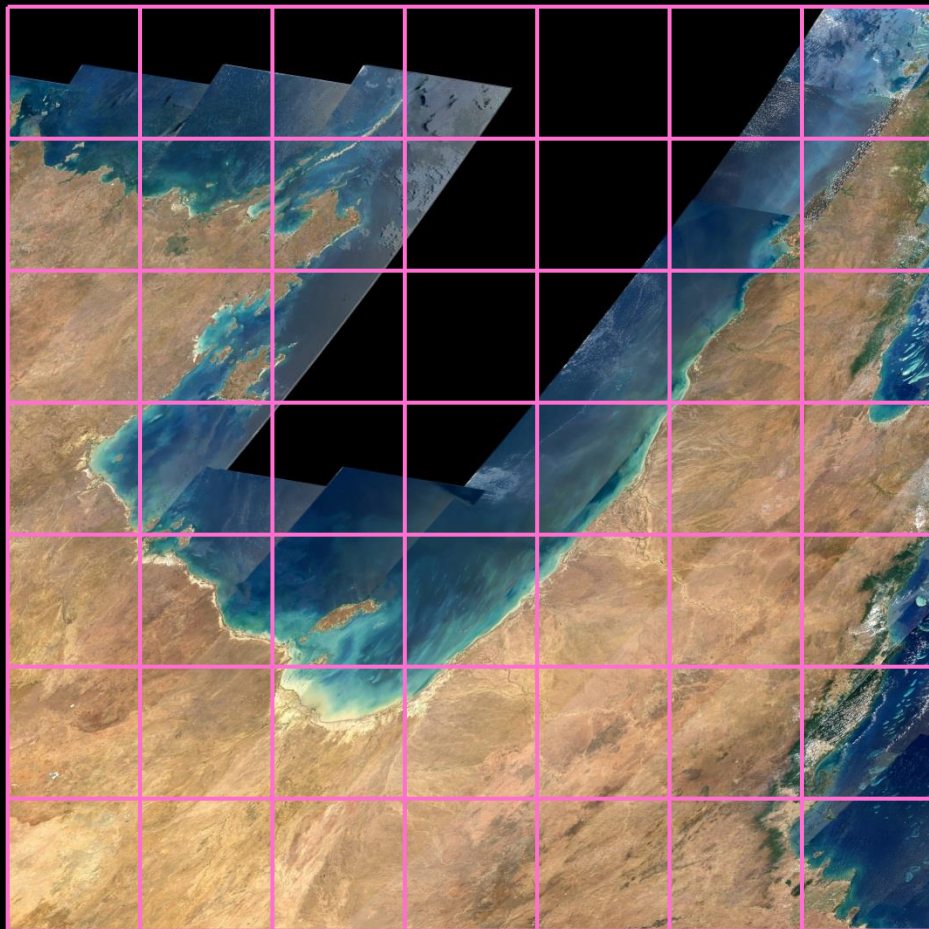
L. DOPE / MODLAND

Each MODIS tile has an area of approximately  $1200 \times 1200$  km ( $10^\circ \times 10^\circ$  at the equator)

Sinusoidal Equal Area Projection



# Global WELD tiling scheme



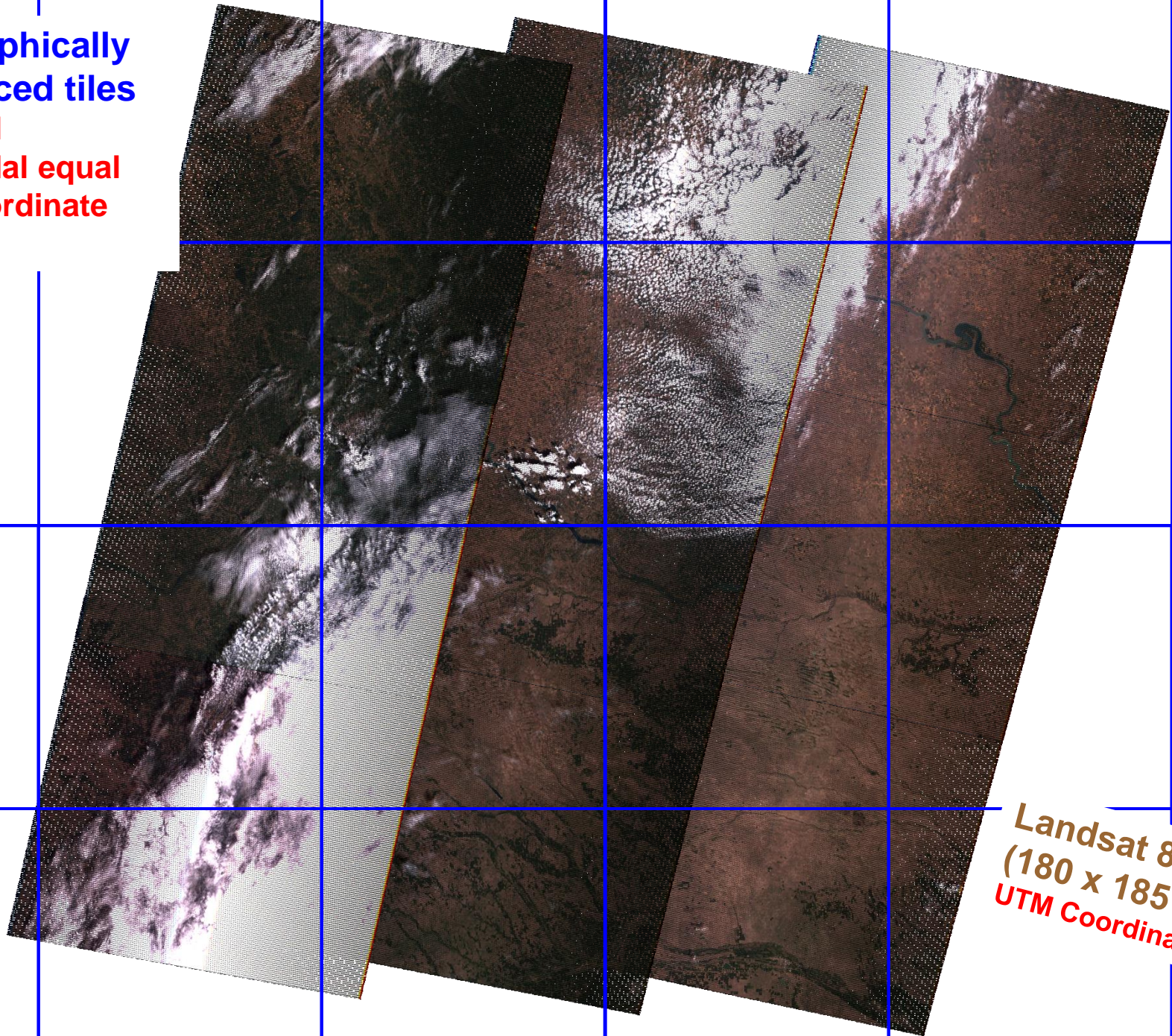
- 7 x 7 global WELD tiles nested within each MODIS 10° x 10° tile
- each WELD tile 5295 x 5295 30m pixels (158 x 158 km)
- Landsat 7 ETM+ & Landsat 5 TOA true color 30m reflectance composite

Human readable global WELD product filenames:

L57.Globe.month09.2009.hh31vv10.h2v1.doy248to273.v2.2.hdf

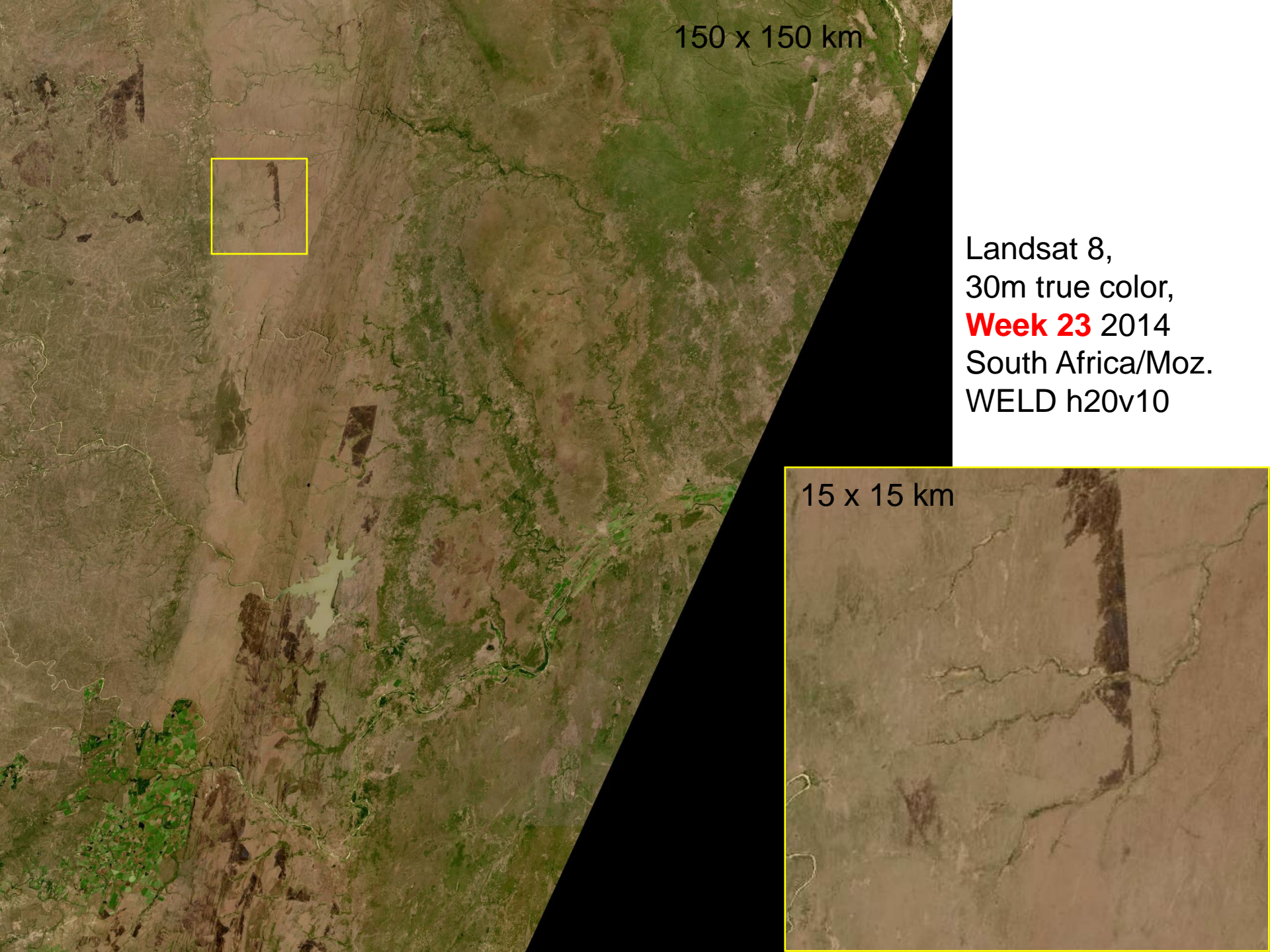


**Geographically  
referenced tiles  
in global  
sinusoidal equal  
area coordinate  
system**



**Landsat 8 L1T  
(180 x 185 km)  
UTM Coordinates**





150 x 150 km

Landsat 8,  
30m true color,  
**Week 23** 2014  
South Africa/Moz.  
WELD h20v10

15 x 15 km

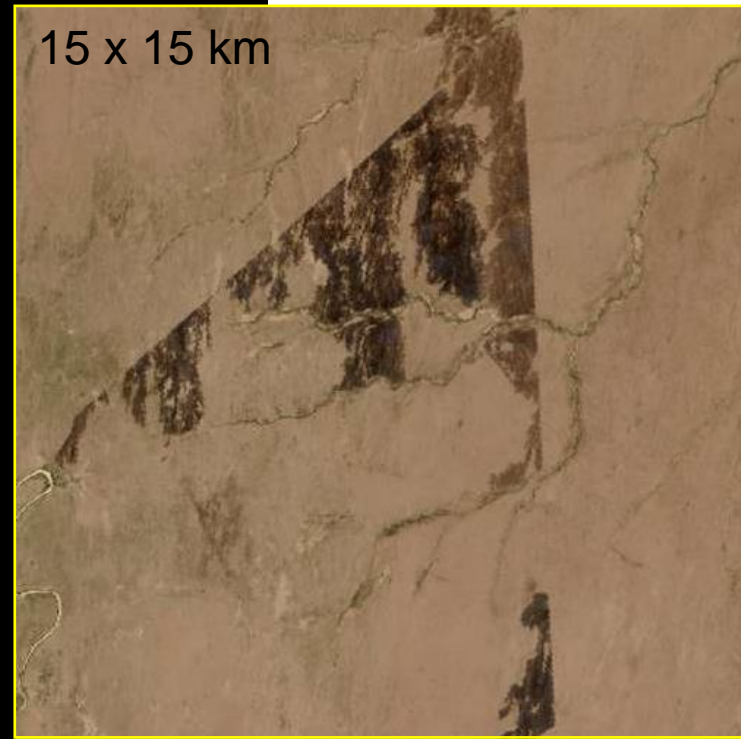


150 x 150 km



Landsat 8,  
30m true color,  
**Week 25** 2014  
South Africa/Moz.  
WELD h20v10

15 x 15 km





150 x 150 km

30m Burned Area  
mapping  
proof of concept

Landsat 8,  
**Week 23 to 25** 2014  
South Africa/Moz.

15 x 15 km

$0.0 \leq f_{cc} < 0.2$

$0.2 \leq f_{cc} < 0.4$

$0.4 \leq f_{cc} < 0.6$

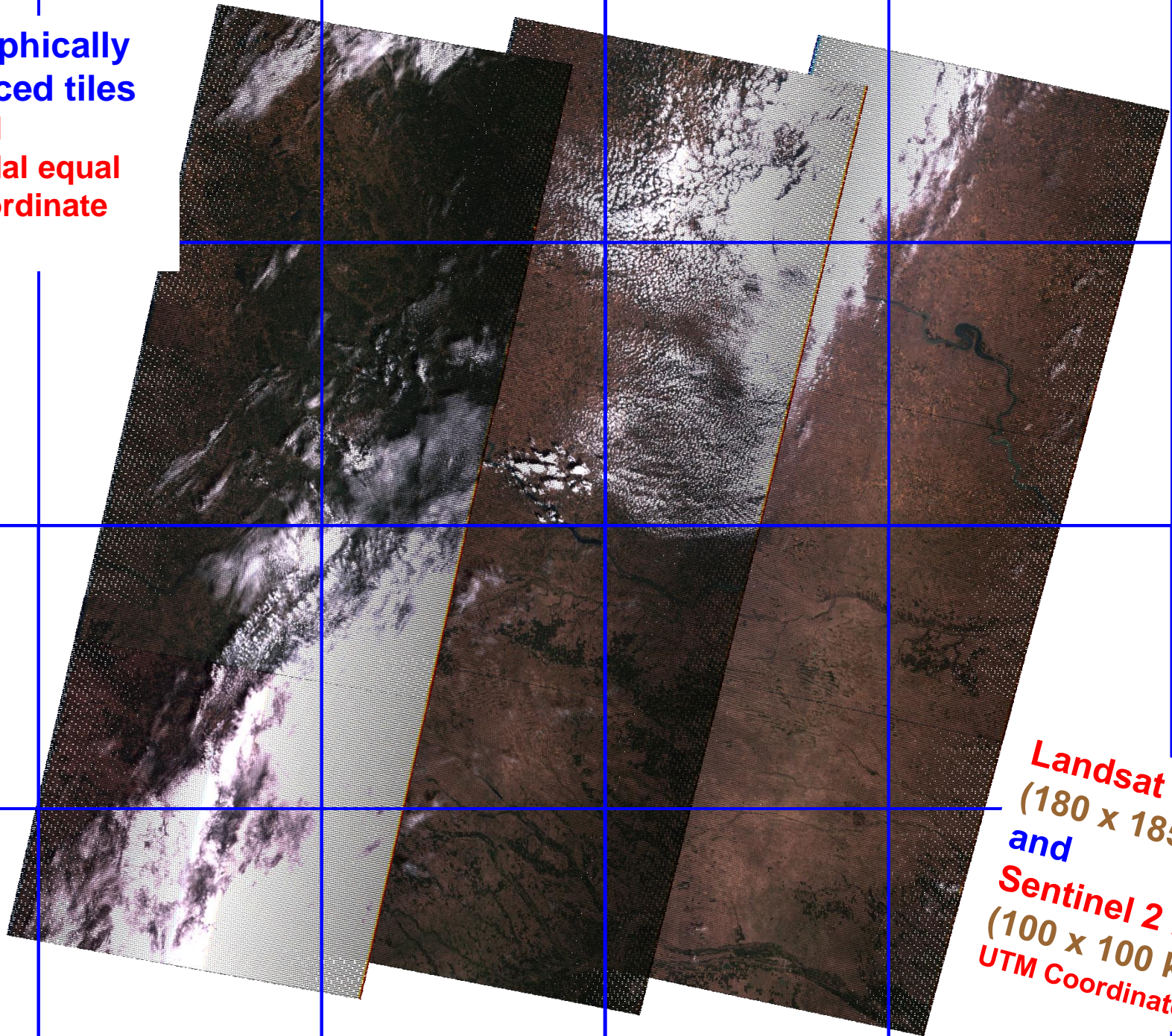
$0.6 \leq f_{cc} < 0.8$

$0.8 \leq f_{cc} < 0.9$

$0.9 \leq f_{cc} \leq 1.0$



**Geographically  
referenced tiles  
in global  
sinusoidal equal  
area coordinate  
system**



**Landsat 8 L1T**  
(180 x 185 km)  
**and**  
**Sentinel 2 L1C**  
(100 x 100 km)  
**UTM Coordinates**



[Overview](#)[Search](#)[Profile](#)[Cart](#)[About](#)Welcome davidroy ! [Logout](#)

Search



S2a\*



Search

[advanced search](#)

Request done : S2a\*

Display 1 to 11 of 11 products



S2A\_OPER\_PRD\_MSIL1C\_PDMC\_20150820T085706\_R051\_V20150815T110427\_20150815T110427  
[https://scihub.esa.int/dhus/odata/v1/Products\('e82b5e56-499b-4ac2-8d51-6a56a5c208c8'\)/\\$value](https://scihub.esa.int/dhus/odata/v1/Products('e82b5e56-499b-4ac2-8d51-6a56a5c208c8')/$value)

Date : 2015-08-15T11:04:27.000Z, Instrument : MSI, Satellite : Sentinel-2, Size : 922.76 MB



S2A\_OPER\_PRD\_MSIL1C\_PDMC\_20150818T101504\_R080\_V20150817T114433\_20150817T114433  
[https://scihub.esa.int/dhus/odata/v1/Products\('b2e58667-7104-4faf-b210-f0d7e9d1c9f0'\)/\\$value](https://scihub.esa.int/dhus/odata/v1/Products('b2e58667-7104-4faf-b210-f0d7e9d1c9f0')/$value)

Date : 2015-08-17T11:44:33.000Z, Instrument : MSI, Satellite : Sentinel-2, Size : 739.70 MB



11  
S2A scenes  
publically  
available  
prior to  
last week of  
November  
2015

Sentinel 2A  
red, green, blue  
TOA reflectance

August 13<sup>th</sup> 2015

Pocking,  
Lower Bavaria

600 x 600  
10m pixels

nearest  
neighbor  
resampled  
to WELD tile





Sentinel 2A  
red, green, blue  
TOA reflectance

August 13<sup>th</sup> 2015

Pocking,  
Lower Bavaria

200 x 200  
30m pixels

nearest  
neighbor  
resampled  
to WELD tile



Sentinel 2A  
red, green, blue  
TOA reflectance

August 13<sup>th</sup> 2015

Pocking,  
Lower Bavaria

200 x 200  
30m pixels

boxcar  
resampled  
to WELD tile





Sentinel 2A  
red, green, blue  
TOA reflectance

August 13<sup>th</sup> 2015

N.W. Austria

boxcar  
resampled to  
global WELD tile  
hh18vv04h6v1

5295 x 5295 30m pixels





Landsat 8  
red, green, blue  
TOA reflectance

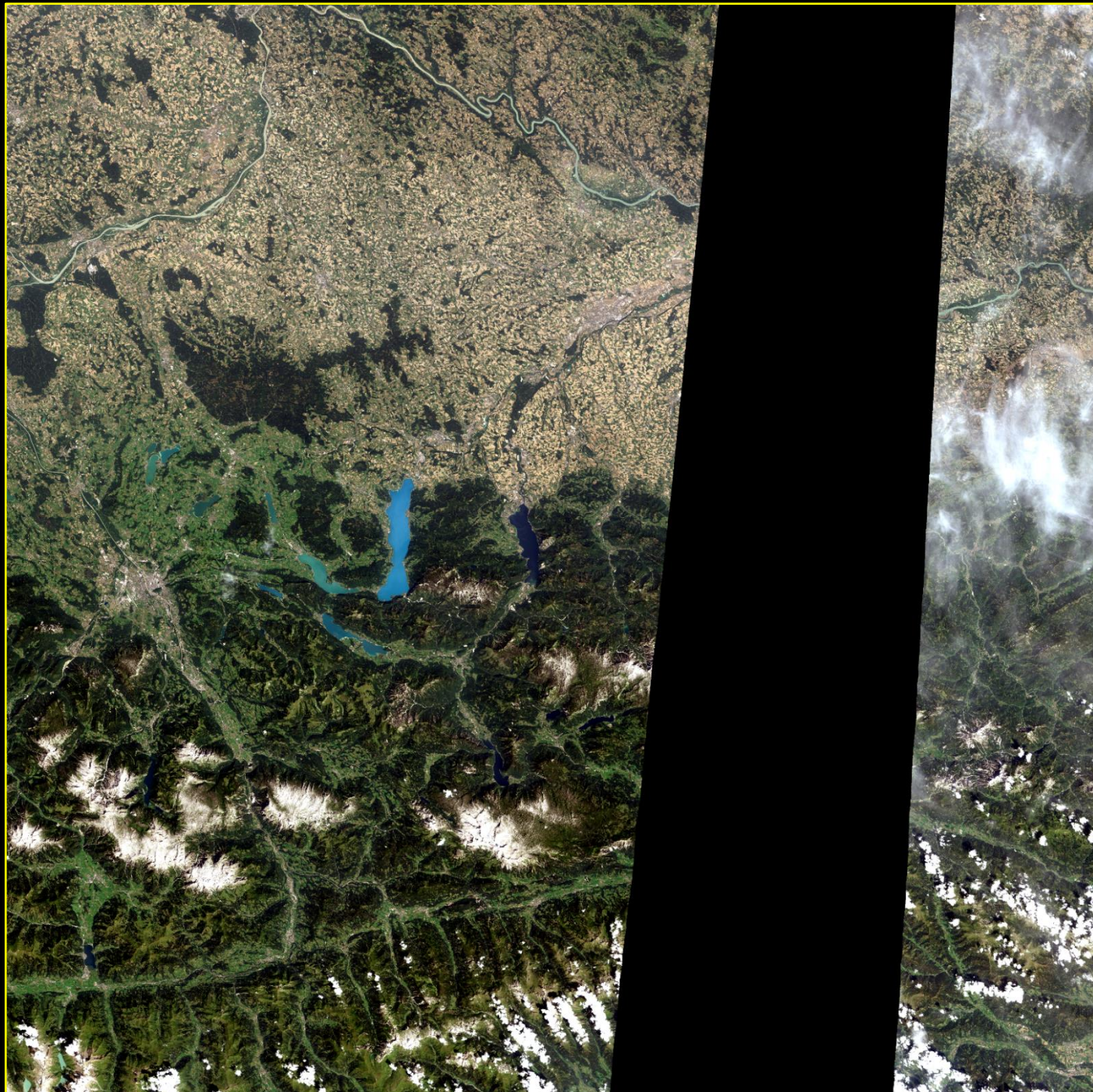
August 9<sup>th</sup> 2015  
(West)

August 11<sup>th</sup> 2015  
(East)

N.W. Austria

nearest neighbor  
resampled to  
global WELD tile  
hh18vv04h6v1

5295 x 5295 30m pixels





Landsat 8  
red, green, blue  
TOA reflectance

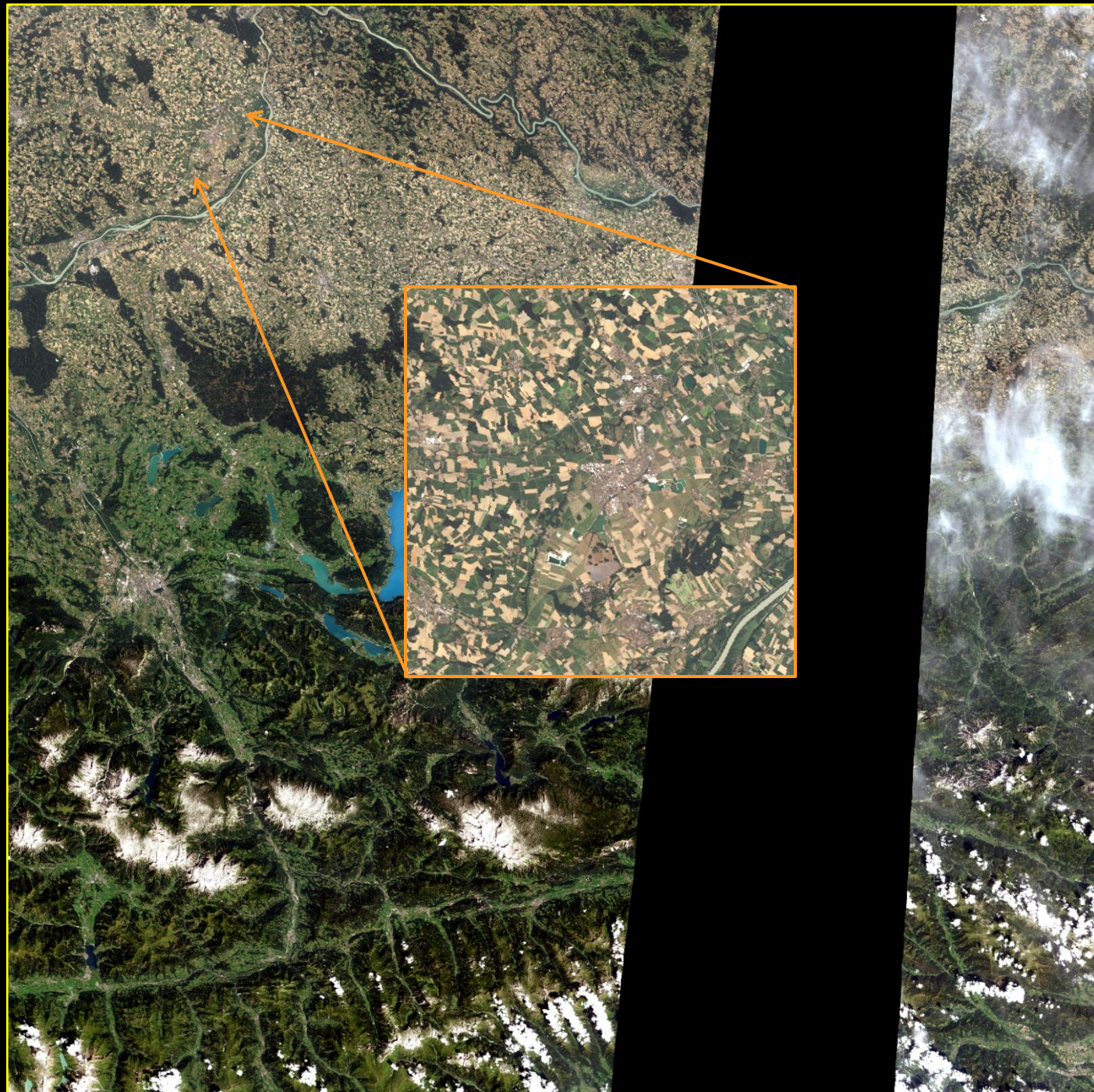
August 9<sup>th</sup> 2015  
(West)

August 11<sup>th</sup> 2015  
(East)

N.W. Austria

nearest neighbor  
resampled to  
global WELD tile  
hh18vv04h6v1

5295 x 5295 30m pixels





Landsat 8  
red, green, blue  
TOA reflectance

August 9<sup>th</sup> 2015  
(West)

Pocking,  
Lower Bavaria

500 x 500  
30m pixels

nearest  
neighbor  
resampled to  
WELD tile  
(hh18vv04h6v1)





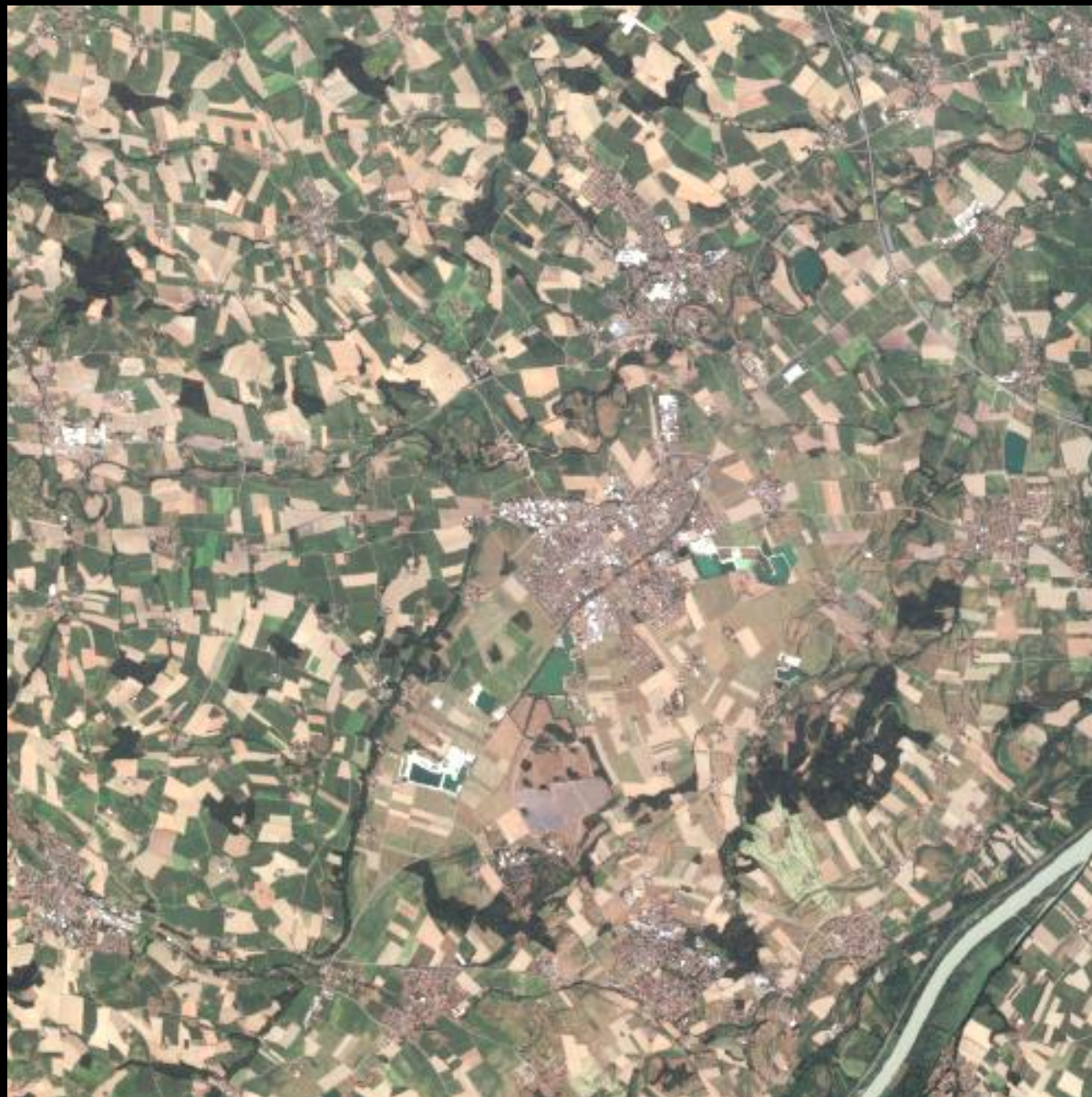
Sentinel 2A  
red, green, blue  
TOA reflectance

August 13<sup>th</sup> 2015

Pocking,  
Lower Bavaria

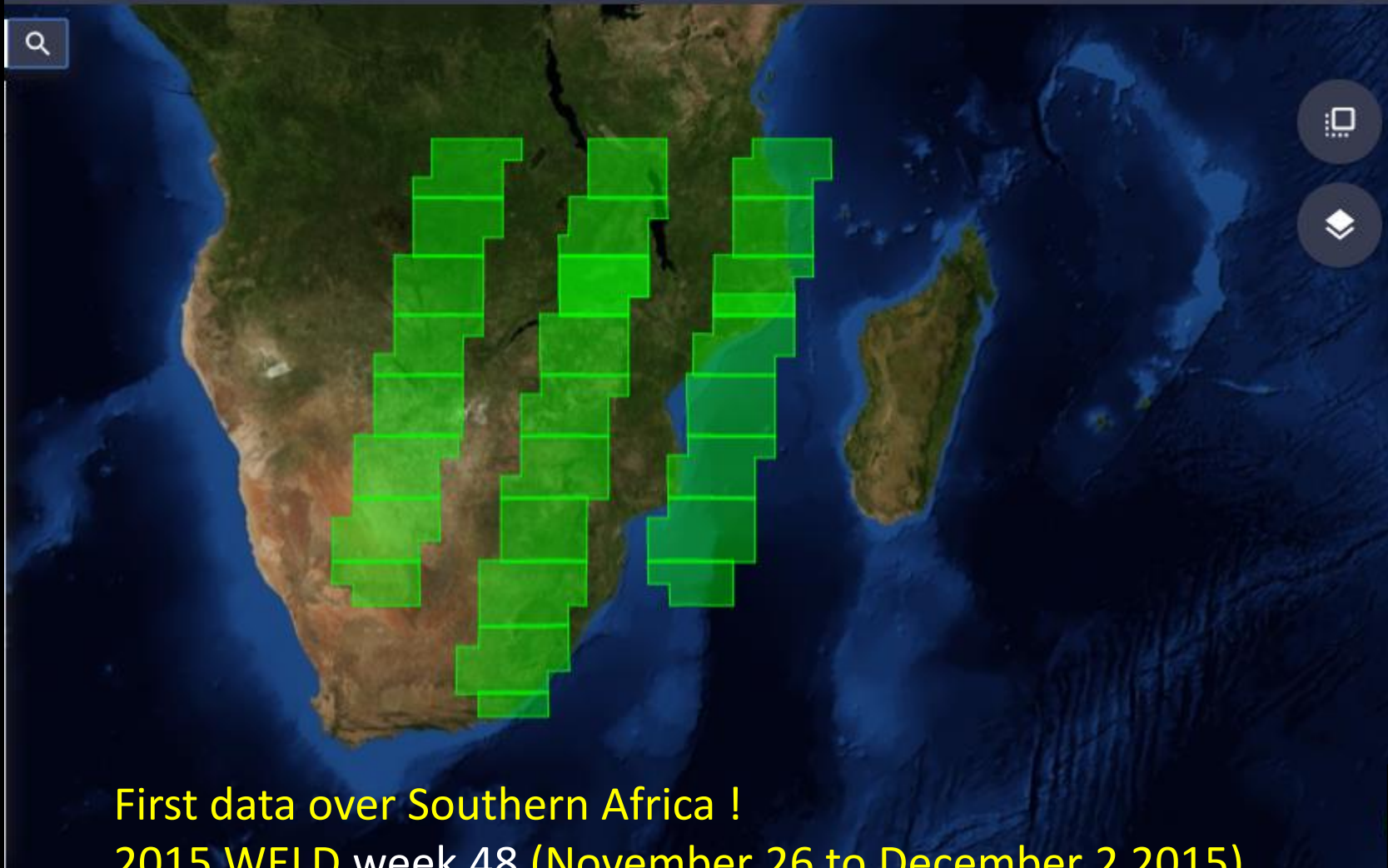
500 x 500  
30m pixels

boxcar  
resampled to  
WELD tile  
(hh18vv04h6v1)





## Sentinel-2 Pre-Operations Hub



First data over Southern Africa !  
2015 WELD week 48 (November 26 to December 2 2015)



Sentinel 2A  
red, green, blue  
TOA reflectance

WELD  
sinusoidal projection  
1.35km browse image

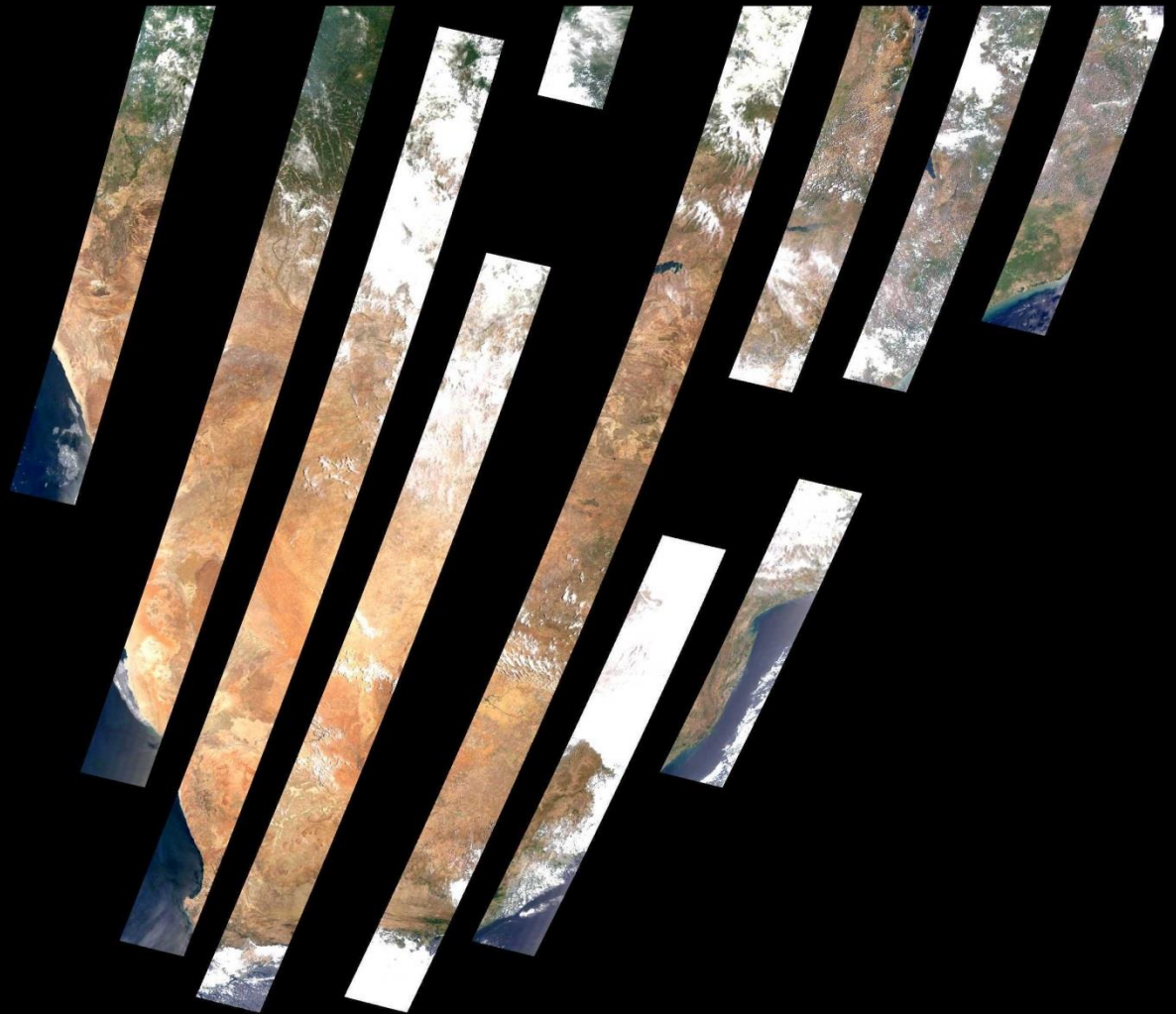


2015 WELD week 48 (November 26 to December 2 2015)



Landsat 8  
red, green, blue  
TOA reflectance

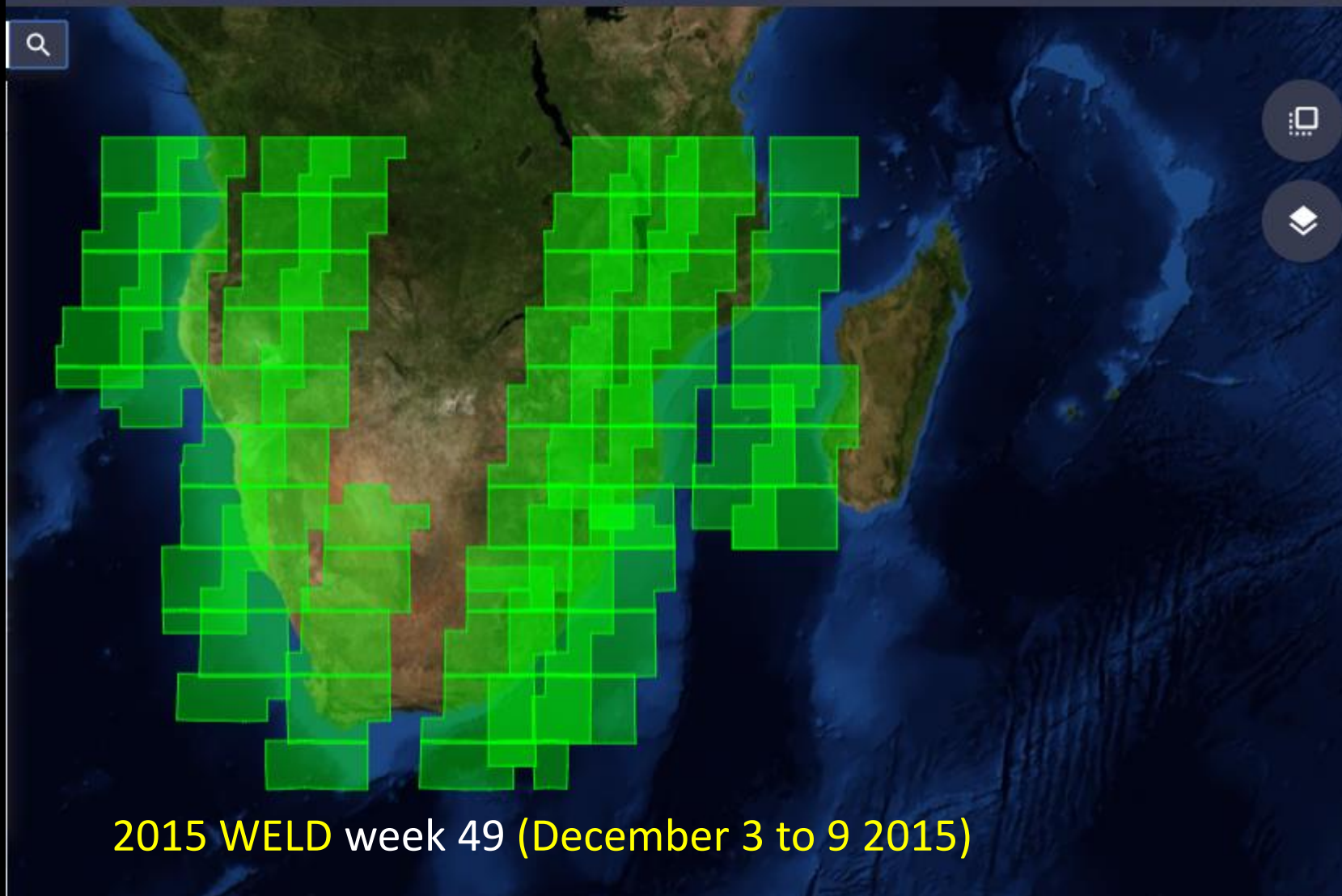
WELD  
sinusoidal projection  
1.35km browse image



2015 WELD week 48 (November 26 to December 2 2015)



Sentinel-2 Pre-Operations Hub

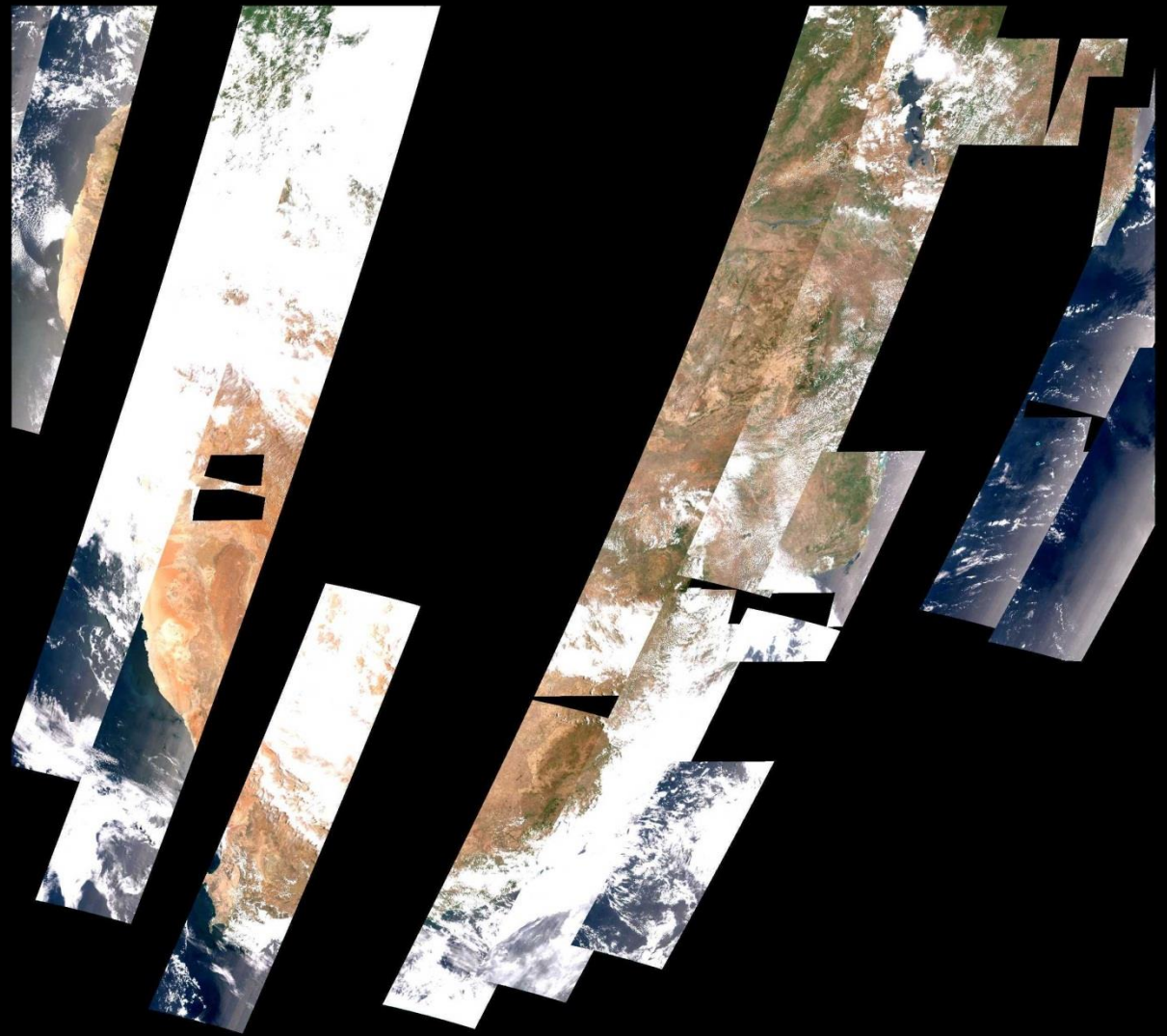


2015 WELD week 49 (December 3 to 9 2015)



Sentinel 2A  
red, green, blue  
TOA reflectance

WELD  
sinusoidal projection  
1.35km browse image



2015 WELD week 49 (December 3 to 9 2015)



Landsat 8  
red, green, blue  
TOA reflectance

WELD  
sinusoidal projection  
1.35km browse image



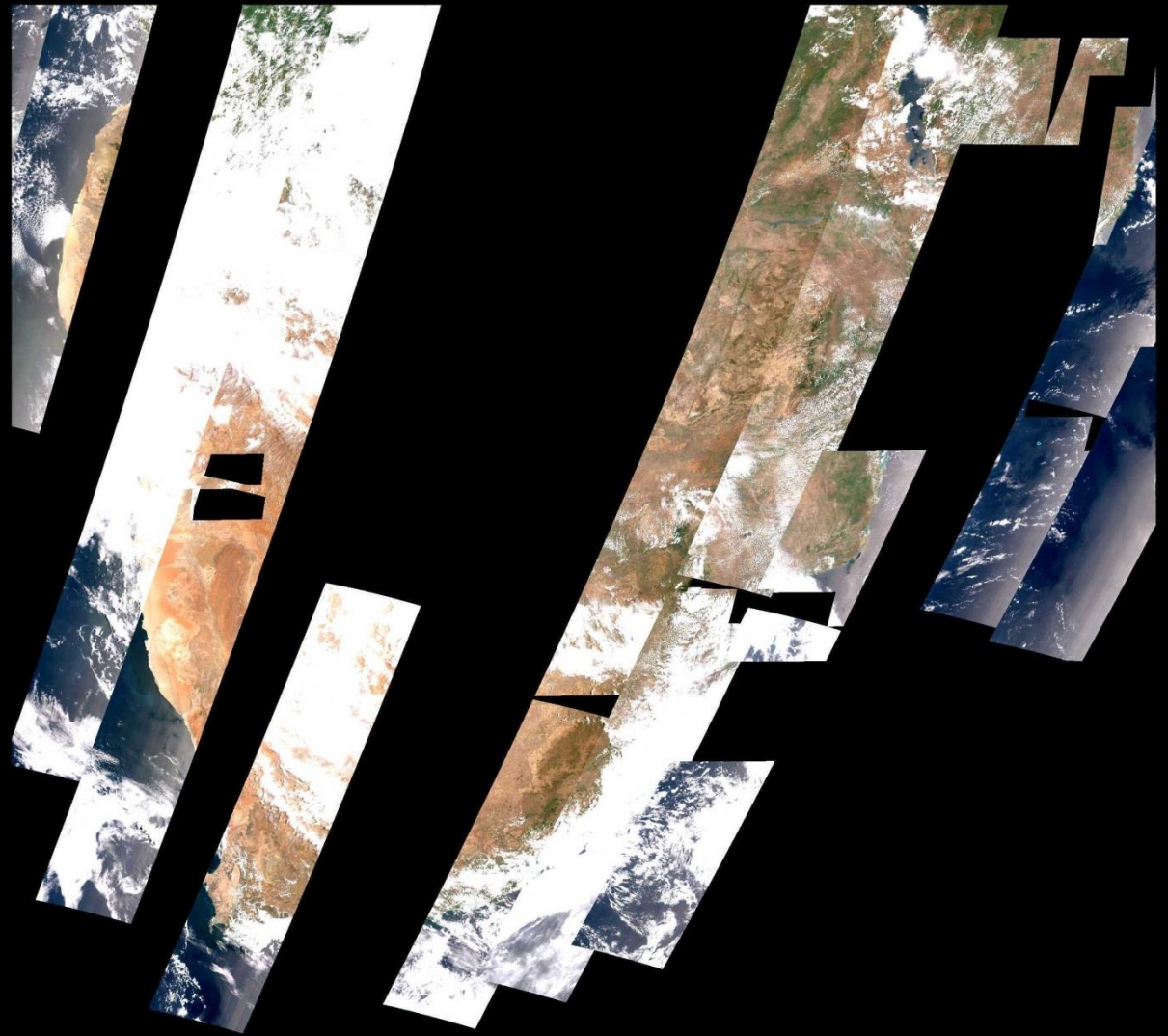
2015 WELD week 49 (December 3 to 9 2015)



Sentinel 2A  
red, green, blue  
TOA reflectance

WELD  
sinusoidal projection  
1.35km browse image

Note, no per-pixel temporal  
compositing applied, just a  
“splat” overwriting by later  
sensor acquisition date



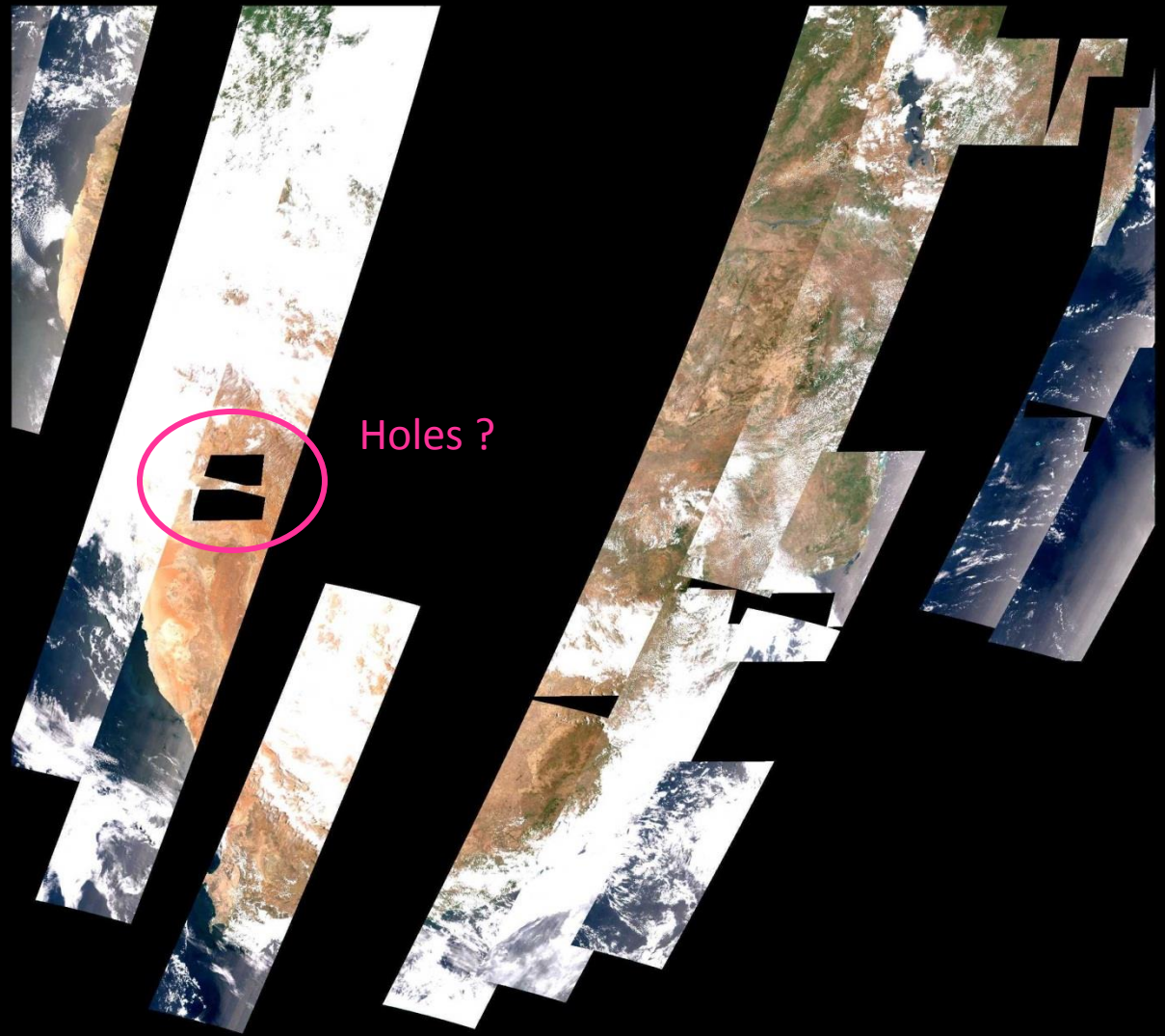
2015 WELD week 49 (December 3 to 9 2015)



Sentinel 2A  
red, green, blue  
TOA reflectance

WELD  
sinusoidal projection  
1.35km browse image

Note, no per-pixel temporal  
compositing applied, just a  
“splat” overwriting by later  
sensor acquisition date



2015 WELD week 49 (December 3 to 9 2015)



Insert search criteria.

Display 1 to 74 of 74 products

Request Done: ( footprint: -35.28333178116743, 41.54111111111111, -13.113020237549605, 9.888888888888889 )

S2A S2A\_OPER\_PRD\_MSIL1C\_PDMC\_20151204T195458\_R064\_V20151204T090648\_20151204T090955

Download URL

Mission: Sentinel-2

https://scihub.copernicus.eu/s2/odata/v1/Products('d1564735-333a-46fb-b195-f571cc103e10')/\$value

Footprint

Quicklook

Attributes

Summary

Date: 2015-12-04T09:06:48.000Z

Instrument: MSI

Satellite: Sentinel-2

Size: 7.13 GB

Product

Instrument

Platform

Inspector

S2A\_OPER\_PRD\_MSIL1C\_PDMC\_20151...090648\_20151204T090955.SAFE

AUX\_DATA

DATASTRIP

GRANULE

HTML

rep\_info

INSPIRE.xml

S2A\_OPER\_BW\_MSIL1C\_PDMC\_20151204T195458\_R064\_V20151204T090648\_20151204T090955.png

S2A\_OPER\_MTD\_SAFL1C\_PDMC\_20151204T195458\_R064\_V20151204T090648\_20151204T090955.xml

Products per page: 150

←

→

×

↓

Example of the *source* of the Africa week 49 S2A browse holes



Insert search criteria.

Display 1 to 25 of 129 p

Request Done: ( footprint  
-41.96626852439496,60.0  
-0.9128105737031262,-6

**S2A** S2A\_OPER\_PRD\_MS  
Download URL  
Mission: Sentin

**S2A** S2A\_OPER\_PRD\_MS  
Download URL  
Mission: Sentin

**S2A** S2A\_OPER\_PRD\_MS  
Download URL  
Mission: Sentin

**S2A** S2A\_OPER\_PRD\_MS  
Download URL  
Mission: Sentin

**S2A** S2A\_OPER\_PRD\_MS  
Download URL  
Mission: Sentin

**S2A** S2A\_OPER\_PRD\_MS  
Download URL  
Mission: Sentin

**S2A** S2A\_OPER\_PRD\_MS  
Download URL  
Mission: Sentin

**S2A** S2A\_OPER\_PRD\_MS  
Download URL  
Mission: Sentin

S2A\_OPER\_PRD\_MSIL1C\_PDMC\_20151209T130109\_R135\_V20151209T082021\_20151209T082021

[https://scihub.copernicus.eu/s2/odata/v1/Products\('6ebb3e76-a3cb-4e39-af42-9fb0ec2c5d90'\)/\\$value](https://scihub.copernicus.eu/s2/odata/v1/Products('6ebb3e76-a3cb-4e39-af42-9fb0ec2c5d90')/$value)

## Footprint



## Attributes

### Summary

Date: 2015-12-09T08:20:21.000Z  
Instrument: MSI  
Satellite: Sentinel-2  
Size: 2.84 GB

### Product

### Instrument

### Platform

## Quicklook



## Inspector

S2A\_OPER\_PRD\_MSIL1C\_PDMC\_20151...082021\_20151209T082021.SAFE

- AUX\_DATA
- DATASTRIP
- GRANULE
- HTML
- rep\_info
- INSPIRE.xml
- S2A\_OPER\_BWIL1C\_PDMC\_20151209T130109\_R135\_V20151209T082021\_20151209T082021.png
- S2A\_OPER\_MTD\_SAFIL1C\_PDMC\_20151209T130109\_R135\_V20151209T082021\_20151209T082021.xml



another hole example ...

Insert search criteria...

S2A\_OPER\_PRD\_MSIL1C\_PDMC\_20151209T143905\_R135\_V20151209T081808\_20151209T081808

[https://scihub.copernicus.eu/s2/odata/v1/Products\('fa321e03-a5ff-4a2e-943d-ceceb8b50a19'\)/\\$value](https://scihub.copernicus.eu/s2/odata/v1/Products('fa321e03-a5ff-4a2e-943d-ceceb8b50a19')/$value)

Display 1 to 25 of 129 p

Request Done: ( footprint  
-41.96626852439496,60.0  
-0.9128105737031262,-6

S2A S2A\_OPER\_PRD\_MS  
Download URL  
Mission: Sentin

S2A S2A\_OPER\_PRD\_MS  
Download URL  
Mission: Sentin

S2A S2A\_OPER\_PRD\_MS  
Download URL  
Mission: Sentin

S2A S2A\_OPER\_PRD\_MS  
Download URL  
Mission: Sentin

S2A S2A\_OPER\_PRD\_MS  
Download URL  
Mission: Sentin

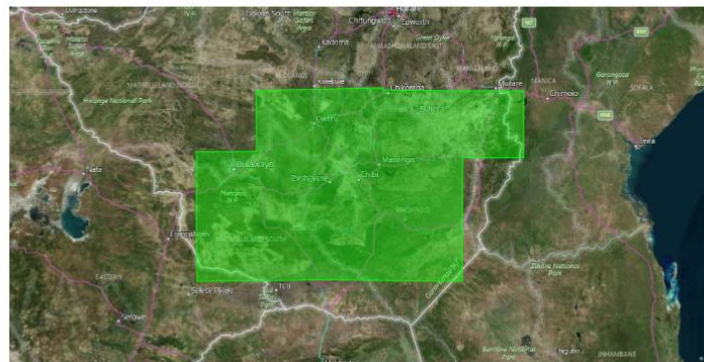
S2A S2A\_OPER\_PRD\_MS  
Download URL  
Mission: Sentin

S2A S2A\_OPER\_PRD\_MS  
Download URL  
Mission: Sentin

S2A S2A\_OPER\_PRD\_MS  
Download URL  
Mission: Sentin

Products per page: 25

### Footprint



### Attributes

#### Summary

Date: 2015-12-09T08:18:08.000Z  
Instrument: MSI  
Satellite: Sentinel-2  
Size: 7.43 GB

#### Product

#### Instrument

#### Platform

### Quicklook



### Inspector

S2A\_OPER\_PRD\_MSIL1C\_PDMC\_20151...081808\_20151209T081808.SAFE

- AUX\_DATA
- DATASTRIP
- GRANULE
- HTML
- rep\_info
- INSPIRE.xml
- S2A\_OPER\_BW\_MSIL1C\_PDMC\_20151209T143905\_R135\_V20151209T081808\_20151209T081808.png
- S2A\_OPER\_MTD\_SAFL1C\_PDMC\_20151209T143905\_R135\_V20151209T081808\_20151209T081808.xml



another hole example ...



Sentinel 2A  
red, green, blue  
TOA reflectance

WELD  
sinusoidal projection  
1.35km browse image

still holes in S2A



2015 WELD week 51 (December 17 to 23 2015)

# Summary #1

- **New moderate resolution data will provide global burned area mapping capability**
  - Combined Landsat 8 / S2A / S2B will provide 3 day global coverage
  - Landsat 8 30m data have improved quantization and signal/noise characteristics
  - Sentinel-2 has Landsat-like bands also at 10m & 20m
- **Developed Landsat 8 and S2A processing under global WELD**
  - S2A reading and data handling
  - reprojection to common WELD projection and tiling
  - Landsat 8 30m nearest neighbor resampling
  - S2A 10m to 30m boxcar resampling
- **Developed Landsat 8 prototype automated burned area 30m mapping algorithm**
  - uses L8 surface reflectance, cloud mask, WELD gridded time series
  - developed a sensor ~agnostic burned area algorithm with good qualitative initial results
- **Future research & development**
  - Continue to integrate Sentinel 2 with Landsat 8 under WELD processing
  - apply burned area algorithm for all Africa & select global samples
  - validate with Planet Labs imagery (**burned area, f**) & Canopy Biomass Lidar (**cc**)



Landsat 8  
red, green, blue  
TOA reflectance

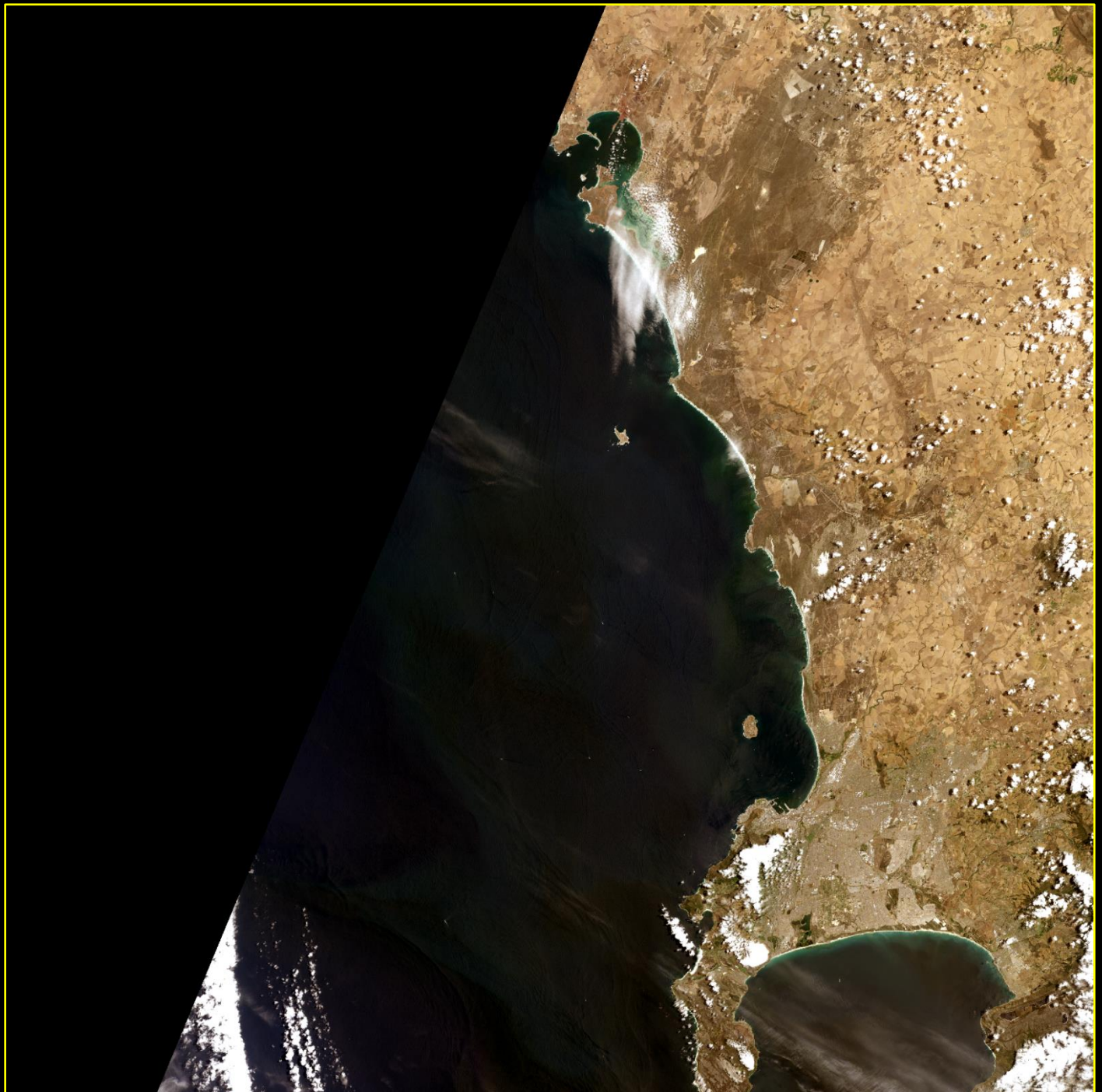
Cape Town,  
South Africa

WELD week 49  
(December 3 - 9 2015)

2 input L1T images  
sensed:  
December 8  
08:35:04  
08:35:28

nearest neighbor  
resampled to  
global WELD tile  
hh19vv12h3v2

5295 x 5295 30m pixels



Sentinel 2A  
red, green, blue  
TOA reflectance

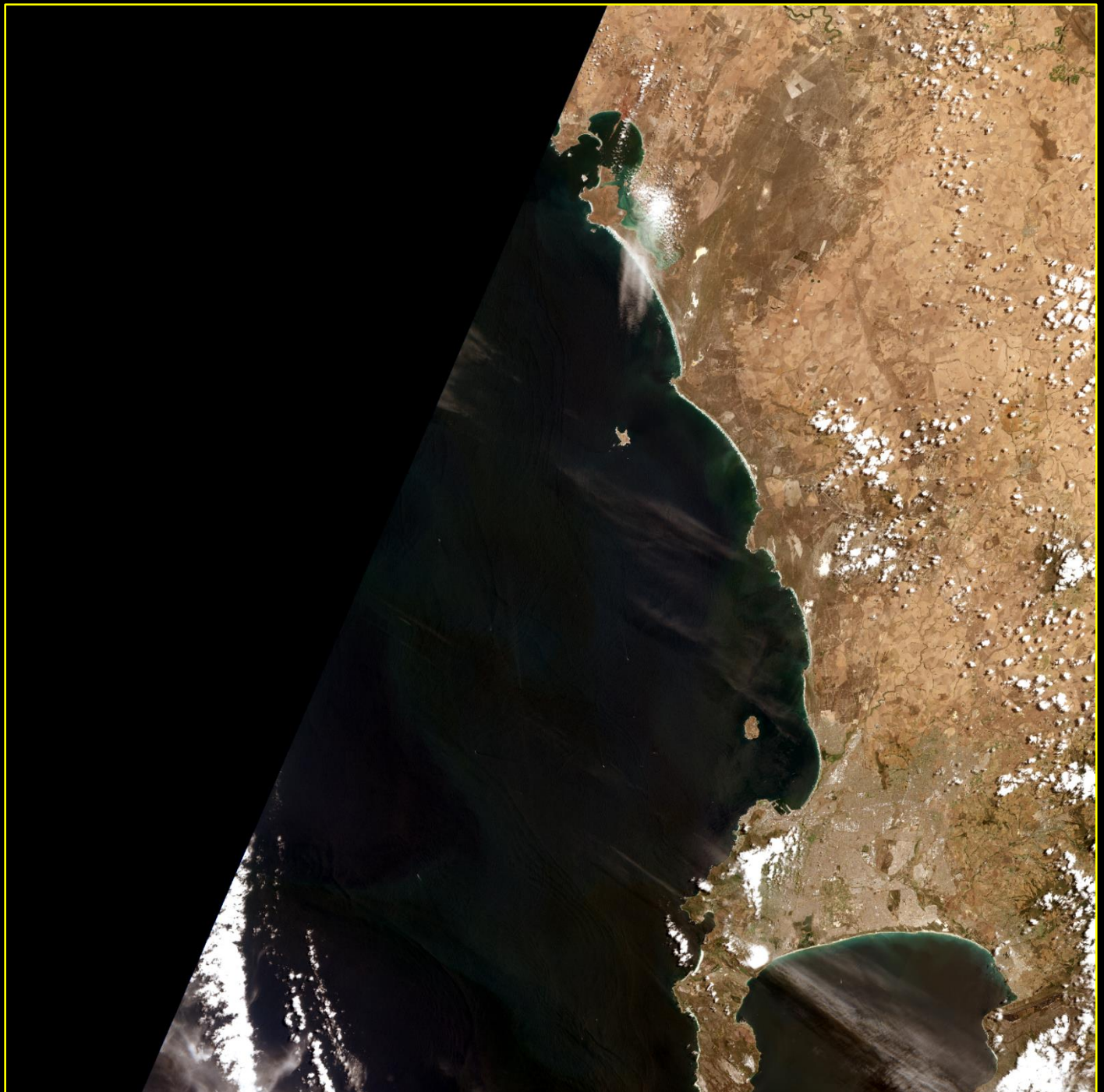
Cape Town,  
South Africa

WELD week 49  
(December 3 - 9 2015)

1 input L1C image  
sensed:  
December 8  
08:50:36

box car  
resampled to  
global WELD tile  
hh19vv12h3v2

5295 x 5295 30m pixels





Landsat 8  
red, green, blue  
TOA reflectance

Koeberg Nuclear  
Power Station &  
Nature Reserve,  
north of Cape Town

WELD week 49  
(December 3 - 9 2015)

2 input L1T images  
sensed:  
December 8  
08:35:04  
08:35:28

nearest neighbor  
resampled to  
global WELD tile  
hh19vv12h3v2

500 x 500 30m pixels



Sentinel 2A  
red, green, blue  
TOA reflectance

Koeberg Nuclear  
Power Station &  
Nature Reserve,  
north of Cape Town

WELD week 49  
(December 3 - 9 2015)

1 input L1C image  
sensed:  
December 8  
08:50:36

box car  
resampled to  
global WELD tile  
hh19vv12h3v2

500 x 500 30m pixels





Landsat 8  
red, green, blue  
TOA reflectance

Koeberg Nuclear  
Power Station &  
Nature Reserve,  
north of Cape Town

WELD week 49  
(December 3 - 9 2015)

2 input L1T images  
sensed:  
December 8  
08:35:04  
08:35:28

nearest neighbor  
resampled to  
global WELD tile  
hh19vv12h3v2

500 x 500 30m pixels

Evident misregistration



Sentinel 2A  
red, green, blue  
TOA reflectance

Koeberg Nuclear  
Power Station &  
Nature Reserve,  
north of Cape Town

WELD week 49  
(December 3 - 9 2015)

1 input L1C image  
sensed:  
December 8  
08:50:36

box car  
resampled to  
global WELD tile  
hh19vv12h3v2

500 x 500 30m pixels

Evident misregistration





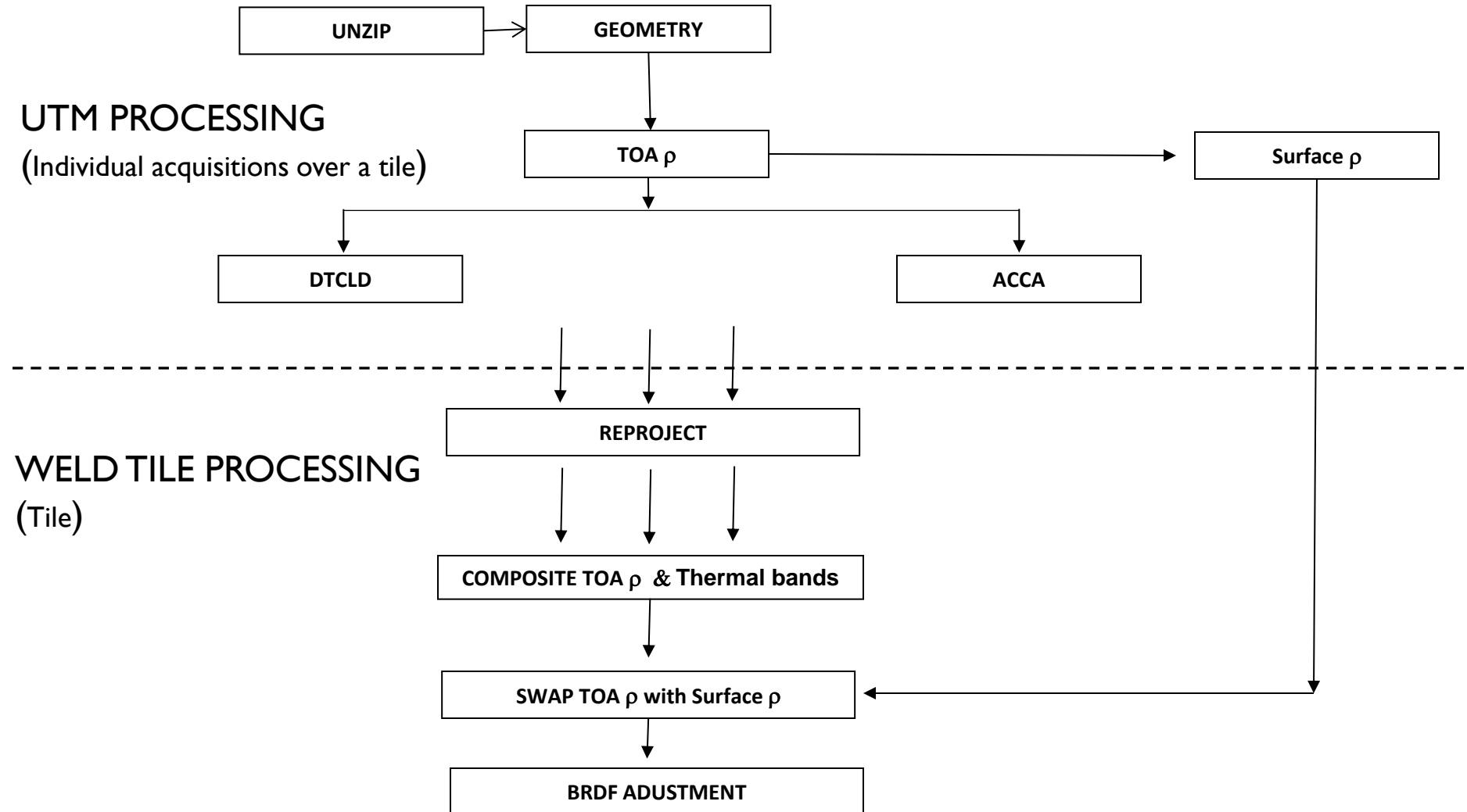
# Summary #2

- **ESA Sentinels Scientific Data Hub**
  - Simple and intuitive
  - Supports scripting via a web service
  - Filenames include sensor and processing date/time
  - Unclear how versioning / reprocessing will be handled
- **S2A data**
  - Holes in L1C products will be an issue for users (not a problem for WELD code, but not cool looking)
  - Cloud and saturation masks missing and appear to be stored as vector files and not as rasters (?)
- **Geolocation**
  - Evident misregistration between Landsat 8 and S2A
    - Know that Landsat 8 is well registered to GLS baseline
    - Don't know if (a) S2A is well registered to S2A global ref. image baseline, (b) GLS is well registered to S2A baseline
    - Need guidance on future improvements of Landsat 8 GLS & ESA global ref. image baselines
  - Working on misregistration analysis between S2A and Landsat 8 defined in the global WELD projection
- **S2A atmospheric correction**
  - Need informed guidance on which ESA atmospheric correction toolkit to use
  - Inter-comparison between ESA-recommended and Landsat 8 atmospheric correction suggested
  - Ideally should have the same L8 and S2A atmospheric characterization and RT solution

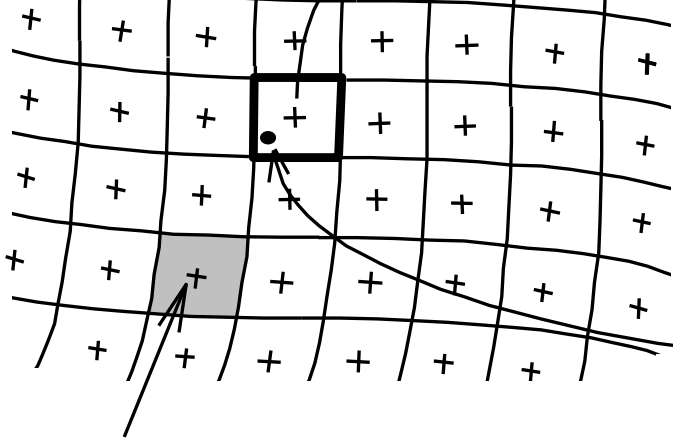
# Global Version 3.0 WELD processing sequence

Will work to generate

- similar but separate L8 and S2 30m gridded products ( prototyped )
- combined L8-S2 gridded 30m products (requires more R&D, see NASA )







**Landsat 8 / Sentinel 2  
Observation  
(UTM projection)**

**Nearest Neighbor**

$$r(x) = \begin{cases} 1 & \text{for } |x| = \frac{1}{2} \\ 0 & \text{otherwise} \end{cases}$$

**Bilinear**

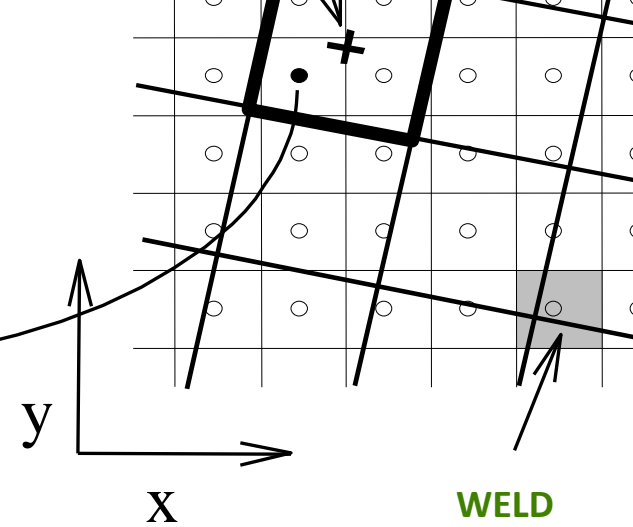
$$r(x) = \begin{cases} 1 - |x| & \text{for } |x| \leq 1 \\ 0 & \text{otherwise} \end{cases}$$

**Cubic convolution**

$$r(x) = r_0(x) + \alpha r_1(x) \quad \alpha \approx -0.5$$

$$r_0(x) = \begin{cases} (2 - |x| + 1)(|x| - 1)^2 & \text{for } |x| < 1 \\ 0 & \text{otherwise} \end{cases}$$

$$r_1(x) = \begin{cases} |x|^2(|x| - 1) & \text{for } |x| < 1 \\ (|x| - 1)(|x| - 2)^2 & \text{for } 1 \leq |x| \leq 2 \\ 0 & \text{otherwise} \end{cases}$$



**WELD  
Pixel  
(Sinusoidal  
projection)**